Evaluation of Uncertainties in decay constants of “short-lived” radionuclides: a meta-analysis approach

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Introduction: Radionuclides with short half-lives on a geologic scale (e.g., 26Al) have given us insights into the formation of our solar systems that were otherwise unattainable. These advances include the discovery of nucleosynthetic input into the solar system within 10⁷ or 10⁸ years of formation in or a ~5Ma formation interval between CAI’s and chondrules. Additionally, due to their short half-lives, short-lived radionuclides hold the promise for a high-precision time-scale of early solar system events if the assumption of homogeneity is met. However, to date numerous authors have shown discrepancies between different short-lived chronometers and long-lived clocks. These discrepancies have multiple plausible causes including analytical issues, thermal effects/metamorphism, genuine heterogeneity, and the value of the half-life that is used.

Results and Discussion: In our work we examine experimental studies measuring the half-lives of various cosmochemically relevant systems (e.g., ¹⁰Be, 26Al, ⁴¹Ca, ⁵³Mn, ⁶⁰Fe, ⁷¹Nb, ¹²⁹I, ¹⁴⁴Sm, ¹⁸²Hf, and ²⁴⁴Pu) through a meta-analysis. We first performed a systematic review of the published experimental determinations, and studies that met our criteria (e.g., measured the purity of their samples, the isotopic ratios and included a description of the analytical considerations) were then combined through a random effects model.

We show that the quality and agreement of the literature varies from system to system. For example, ¹⁰Be has four studies which met our criteria for inclusion and the agreement between them was fairly good. On the other hand for ¹²⁹I no study met our criteria for inclusion. Additionally, recently published studies have suggested that the half-lives for both ⁶⁰Fe and ¹⁴⁴Sm need considerable revision.

We can provide recommended half-lives for various systems (e.g., 26Al) but for others conclude that the value is only semiquantitatively known (e.g., ⁵³Mn). A further consideration is the inclusion of appropriate uncertainties on half-life measurements when dating early solar system events. For example, in the 26Al system, using our new estimate of the half-life, the propagated uncertainties in the age of the Efremovka E-60 CAI⁸ to D’Orbigny⁹, would increase from ~80ka to ~260ka. With the uncertainties present in the decay constant literature, it is necessary for further experimental work to be undertaken before a robust short-lived chronology can be developed, or for inter-radionuclide heterogeneities to be uncovered.